LABOR… AL

OF

FIRST YEAR SCIENCE

JOSEPH L. THALMAN

ADA L. WECKEL

Compliments
of

an

LABORATORY MANUAL

OF FIRST YEAR SCIENCE FOR HIGH SCHOOLS

BY

JOSEPH L. THALMAN, A.M.,
HEAD OF BIOLOGY DEPARTMENT, OAK PARK AND RIVER FOREST TOWNSHIP HIGH SCHOOL

AND

ADA L. WECKEL, A.M.,
INSTRUCTOR IN BIOLOGY DEPARTMENT, OAK PARK AND RIVER FOREST TOWNSHIP HIGH SCHOOL
OAK PARK, ILLINOIS.

ANN ARBOR:
THE ANN ARBOR PRESS
1911

PREFACE.

Because of the present general demand for a course in first year science in the high school, this manual has been prepared. As stated in the introduction by Principal J. C. Hanna, the father of the elementary science idea as embodied in this manual, "these exercises are the result of twelve years of experiment and search for interesting and fundamental scientific matter adapted to the age and preparation of pupils entering the high school." In their present form, they have been used in this school the past two years.

A child's first knowledge of science does not deal with the differentiated sciences as such. He comes in touch with science in all its phases. This course aims to acquaint him with some of the elementary truths of the physical, as well as the biological, sciences with a unified body of knowledge, by a logically arranged series of experiments.

All experiments, unless marked "Demonstration," are performed by the student, who thus gains his knowledge first-hand from the experiment.

The history of the course has been given by Mr. Hanna in the introduction. The authors wish to emphasize the obligations they are under to those teachers who have in any way assisted in this work, especially to Messrs. Robison and Large, for the great part they have had in carrying this experiment through its various stages, and to

express their appreciation in having the opportunity of collecting together the "loose ends" into a unified whole.

All available material has been used in the preparation of these exercises. The figures have been prepared by students and were drawn from the apparatus.

We hereby extend to Mr. J. C. Hanna our sincere thanks for writing the introduction to this course, and for his sympathetic interest and faith, which have made this manual possible.

OAK PARK, ILL., J. L. T.
1911. A. L. W.

TABLE OF CONTENTS.

INTRODUCTION.

The original notion, which is responsible for this book, came to the writer of this introduction twenty years ago while a teacher of Latin and Greek in Columbus, Ohio, and he has pushed hard ever since, for a solution of the elementary science problem in the general direction here indicated.

The credit for the work done belongs, of course, to the zeal, loyalty, patience and skill of the specialists, who have set themselves to the actual solution of the problem during the last twelve years in the Oak Park and River Forest Township High School. It has all been pioneer work and the course in actual operation has shifted every year. Credit is due to Mr. Clarence L. Robison, now of Montclair, N. J., for clearing the ground during the four years, 1898-1902, while in charge of the work here. His successor, Mr. Thomas Large, performed a heroic task in bringing into some degree of harmony three things: (1) the ideas of the writer as outlined below: (2) the statutes regarding instruction in human physiology, and (3) scientific accuracy.

Other science instructors in the school have contributed generously of effort and suggestion from time to time, but the chief work has been done by the two instructors whose names appear on the title page, and who are abundantly entitled to the credit that will be given them, for this making real of a vague idea, which was in the mind of another when they were little children.

This course, then, is the result of long years of experiment and search, by sympathetic instructors, for interesting and fundamental scientific matter, adapted to the age

and preparation of pupils entering the high school. Within this period, from six to twelve classes per year have pursued the course; hence the outline, now fairly fixed, represents the net result of work with about one hundred sections.

This experimental work has been the practical outworking of certain fundamental beliefs, viz:

(a) that certain preliminary science study of some sort should be done in the high school before the regularly accepted laboratory courses in physics, chemistry, botany, zoölogy, and physiography are taken up;

(b) that such elementary studies are advisable for all pupils, whether the more advanced laboratory work is taken up later or not;

(c) that, aside from the training value in such studies, consideration should be given to the matter of content with reference to the practical usefulness of the actual knowledge acquired; such consideration will demand the study of elementary truths that might be classified under several different heads, as physics, chemistry, physiology, botany;

(d) that useful familiarity may thus be acquired with simple laboratory methods and apparatus which will save time in the pursuance of more advanced courses;

(e) that some familiarity with the scientific method of atack thus acquired in dealing with experiments under several heads, as physics, phyisology, botany, etc., will tend to develop early the "scientific" habit which will be of use in every department of study;

(f) that this, and the other aim enumerated, may be reached better by such a course than by any course confined to the facts and problems of any one of the fields of study named above.

The testing of the plan by experiment has taught all concerned many things, including a certain modesty, but

it has only confirmed these fundamental beliefs. For the past two years, no pupil, in the six hundred that have taken this course, has expressed dissatisfaction with it, while the testimony of observing teachers in other departments —both scientific and literary—is unanimously and heartily to the effect that all pupils are helped by this course in their equipment for the studies of the more advanced years in the high school.

As presented in this school, it is taken on alternate days with a course in freehand drawing, or in manual training, or, (for a few), in business arithmetic. In practice this plan works well and allows the training in the first year in five of the lines of study indicated by Dr. Harris—the history, (except as the same is suggested in our English work) being postponed till the second year.

I wish to congratulate the authors on the completion of the course, and to express a modest belief that a reward will come in the way of recognition of so thorough and honest a piece of work, seemingly so well adapted to the need of high school pupils.

JOHN CALVIN HANNA.

OAK PARK, ILLINOIS, July 7, 1911.

CHAPTER I.

MATTER.

It is natural for us in the beginning of the study of a new subject to want to know at once what we are going to study. Science is a new word to us and no doubt there are as many ideas of its meaning as there are students in the class. However, we shall learn as we proceed with this work, that we are dealing with very common things that are going on round about us daily.

Some of the subjects we shall study, perhaps we feel we know from our daily observation. All of us know water flows down hill and not up; that a stone thrown up into the air returns to the earth again. Yet have we stopped to learn why these facts are true? To answer these and similar questions is the work of science. It deals with seeking out the truth concerning nature.

As a name for the substance dealt with in this General Science, let us assume the term matter. Then the question naturally arises—What is matter?

Most authors agree on the definition: "Matter is anything occupying space or having weight." Thus, it will be seen at once that wood is matter and that water is matter. But does matter exist only in the visible form?

EXERCISE I. Is Air Matter?

OBJECT: To determine whether air is matter.

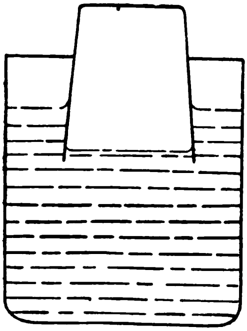


Figure 1

APPARATUS: Glass tumbler.
Large glass jar.

DIRECTIONS: Fill the glass jar three-quarters full of water. Push the tumbler, mouth downward, half way under the surface of the water. Does the water rise to fill the tumbler? Does it rise into the tumbler at all? What prevents it from filling the tumbler? To answer this question tilt the tumbler sidewise allowing a few bubbles to escape. Was the tumbler empty? What did it contain? Is this matter and why? Air is a gas.

Matter exists in three forms, solid, liquid and gas. Solids are substances which have a definite size and shape, which cannot be changed except by some external force. Liquids have a definite size, but the shape depends upon the containing vessel. Gases have neither a definite size nor shape, but expand without limit.

CHAPTER II.

CONSTITUTION OF MATTER.

EXERCISE 2. Diffusion of Liquids.

OBJECT: To determine whether liquids will diffuse when in contact.

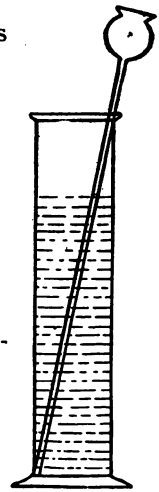


Figure 2

APPARATUS:
- Thistle tube.
- Glass cylinder.
- Metric rule.
- Saturated solution of copper sulphate.
- Distilled water.

DIRECTIONS: Fill the glass cylinder two-thirds full of distilled water. Into the cylinder place the thistle tube with the bulb upward. When the water is quiet, slowly pour through the thistle tube 50 cubic centimeters of copper sulphate solution. This must be done as carefully as possible to avoid mixing the liquids. What is now the relative positions of the liquids? Is there a sharp line of separation between the liquids? Why is the copper sulphate solution placed on the bottom of the glass cylinder? Measure accurately with a metric rule the

height of the copper sulphate solution. Record observations and allow the experiment to remain undisturbed until the next recitation period. Then repeat the observations made above. What changes? In conclusion what have you learned from this experiment?

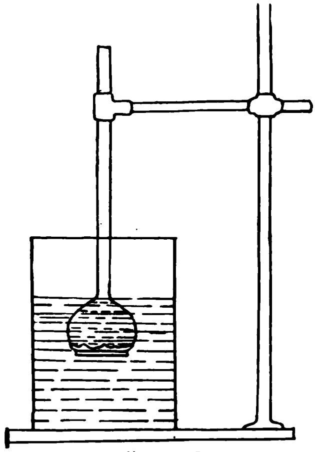


Figure 3

EXERCISE 3. Diffusion of Liquids through a Membrane.

OBJECT: Will liquids diffuse if separated by an animal membrane?

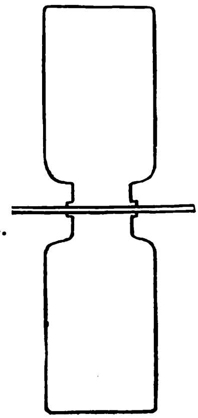
APPARATUS:

Animal membrane.
Thistle tube.
Water.
Molasses.
Twine.
Glass jar.
Ring stand and clamp.
Rubber tubing.

DIRECTIONS: Over the stem end of the thistle tube fit a small piece of rubber tubing. Close this tightly with a clamp. Fill the bulb of the tube with dilute molasses. Over the end of the bulb securely tie an animal membrane being careful to exclude all air bubbles. From the ring stand suspend the tube with the bulb in a jar of water. Mark the level of the molasses in the tube. Note the color of the water in the jar. At the end of one hour repeat the same observations. Observe again at the end of twenty-four hours. What changes have taken place? Has any molasses passed into the water? How do you know? Has any water passed into the molasses? In which direction has diffusion taken place more rapidly? How do you know?

EXERCISE 4. Diffusion of Gases.

OBJECT: Will gases diffuse when in contact?



APPARATUS: Gas generator.
Lime water.
Wide-mouthed bottles.
Glass covers.

Figure 4

DIRECTIONS: From a gas generator fill a bottle with carbon dioxide gas. Carbon dioxide gas is heavier than air so displaces the air which was in the bottle. Pour lime water into the bottle. By shaking the bottle thoroughly mix the lime water with the carbon dioxide gas. What change do you note in the lime water? Such a change in lime water indicates the presence of carbon dioxide gas. From the generator fill another bottle with carbon dioxide gas. Cover the bottle with a glass plate and remove it to your desk. Over the mouth of this bottle invert a bottle of air and then remove the glass plate. Allow the bottles to stand in this relation five minutes. Remove the upper bottle and cover it immediately with the glass plate. Is there any carbon dioxide gas in the upper bottle? How do you determine this?

EXERCISE 5. Diffusion of Gases. (Demonstration).

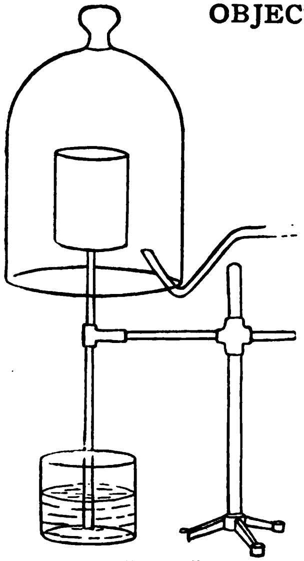


Figure 5

OBJECT: Will gases diffuse through a porous wall?

APPARATUS: Porous cup with glass tube inserted.
Ring stand.
Cup of colored liquid.
Battery jar.
Illuminating gas.

DIRECTIONS: From the ring stand suspend the porous cup apparatus with the free end of the glass tube projecting into the cup of colored liquid. Fill the battery jar with illuminating gas, then quickly lower it over the porous cup. What change takes place at the end of the glass tube in the colored liquid? Remove the battery jar. What change do you now observe? In the first instance what were the bubbles escaping? Where did they come from? What must have been the condition in the porous cup to produce such a result? How do you account for it? What must have been the condition to cause the liquid to rise in the tube when the battery jar was removed? What does this exercise teach?

CONSTITUTION OF MATTER.

From the exercises in chapter two, you have learned that liquids diffuse when in contact and also when separated by an animal membrane; also, that gases intermingle when left in contact or even separated by a porous wall. The fact that the copper sulphate gradually rose into the water in the cylinder and the carbon dioxide gas rose from the lower bottle into the one placed over it, indicates that one substance passed into another. That this can happen, the substances must be composed of "particles" with "spaces" between them. Thus the "particles" of one substance would seem to pass into the 'spaces" of the other. So reasoned the discoverers of this phenomenon and gave to science an explanation called the "Molecular Theory of Matter." According to this theory all matter is made up of very small particles called molecules, with very small spaces between them called intermolecular spaces. The actual size of molecules is unknown. They are so small that they can not be seen even with the highest power microscope. According to some calculations the average diameter of molecules is 1/62,500,000 of an inch. Molecules of any one substance are all of the same size, but of different size in another substance. Thus molecules of water are all of the same size but they differ in size from those of sulphur.

Molecules are conceived as being in constant motion, moving back and forth in the intermolecular spaces. The size of the spaces and the motion of the molecules vary with the state of matter. In solids the movement is most restricted because the spaces are smallest. In gases, on the other hand, the activity of the molecules is greatest and the spaces largest.

CHAPTER III.

SOME FORCES WHICH AFFECT MATTER.

EXERCISE 6. Effect of Heat on Solids.

OBJECT: To determine the effect of the change of temperature on the volume of a solid.

APPARATUS: Brass ball.
Brass ring.
Bunsen burner.
Compound bar.

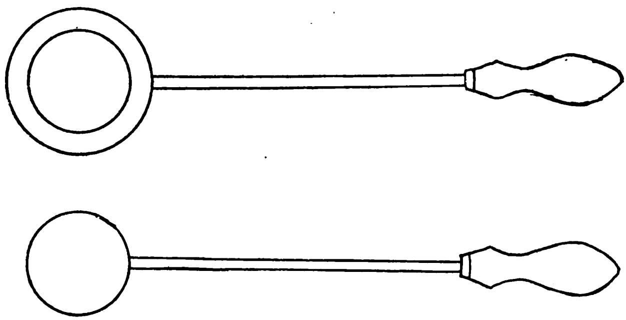


Figure 6

DIRECTIONS: (a) Try the fit of the ring over the ball. Heat the ball. Will the ball now pass through the ring? Heat the ring. Will the ball now pass through the ring? From these observations what change do you conclude must have taken place in the volume of the two solids?

(b) Do all solids expand at the same rate?

For your answer heat the compound bar. Do you observe any change in the direction of the bar? How do the two bars now compare in length?

EXERCISE 7. Effect of Heat on Liquids.

OBJECT: Does the volume of liquids change with a change in temperature?

APPARATUS: Test-tube.
One-hole rubber stopper.
Glass tube.
Bunsen burner.

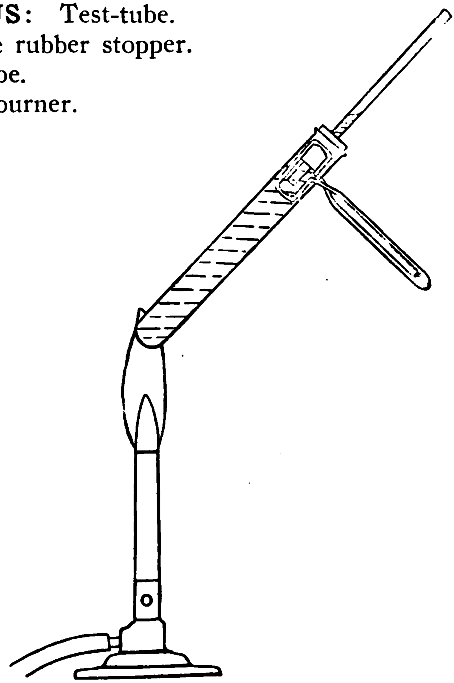


Figure 7

DIRECTIONS: Fill the test-tube with cold water. Into the mouth of the tube insert the rubber stopper fitted with a glass tube. Press on the stopper until the water rises about an inch in the glass tube. Mark carefully the level of the water.

Heat the water gently by playing the flame of the Bun-

sen burner along the side of the test-tube. What change do you observe in the water level?

Again mark the level of the water. Cool the water in the test-tube by running tap water over it or by surrounding the test-tube with ice. After a few minutes note the level of the water.

Did the amount of water increase with the increase of temperature? Did it decrease with a lower temperature? Then how do you explain the increase and decrease in volume noted upon heating and cooling respectively?

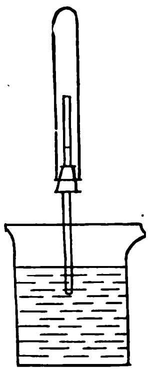


Figure 8

EXERCISE 8. Effect of Heat on Gases.

OBJECT: To determine the effect of a change of temperature upon the volume of gases.

APPARATUS: Test-tube.
One-hole rubber stopper.
Bunsen burner.
Beaker of colored liquid.

DIRECTIONS: Fit the stopper with the glass tube into the test-tube as in the preceding exercise. With what is the test-tube filled? Is this a gas? See Exercise 1. Place the projecting end of the glass tube into the beaker of colored liquid. Heat the tube gently with a Bunsen flame. Observe carefully all changes. Does this change indicate an increase in the amount of gas in the test-tube or in its volume? Without changing the apparatus allow the gas in the test-tube to cool. What change do you now observe? How do you account for the change? From the last three exercises what is the effect of the increase of temperature upon the molecular spaces? Upon the molecules? The effect of the decrease of temperature upon the molecular spaces? Upon the molecules?

EXERCISE 9. Cohesion, Adhesion and Gravity.

OBJECT: A study of forces acting between molecules and between masses.

APPARATUS: Spring balance.
Circular glass plate.
Battery jar.

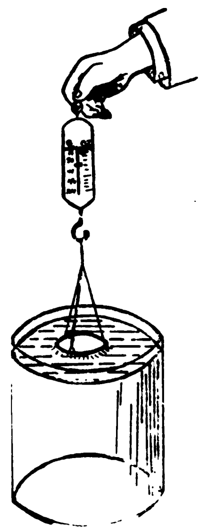


Figure 9

DIRECTIONS: By means of sealing wax, attach three strings at equidistant points near the margin of the glass plate. Tie the ends of the strings together and suspend the plate from the hook of the spring balance. (The glass plate must hang horizontally.) Record the weight of the glass plate. Then lower the apparatus over the battery jar filled with water, until the plate touches the water. Slowly lift the balance at the same time noting any changes in the reading on the index of the balance. Continue to lift the balance. What happens? Examine the under surface of the plate. What do you find there? Does this indicate that the plate was separated from the water or that the water particles were pulled apart?

Thus it will be seen two forces were acting, the one holding the molecules of water together called cohesion, the other holding the plate to the water, adhesion. Which in this experiment was the greater? With the water still adhering hold the plate in a vertical position. What happens to the water? This third force causing the water to drop is called gravity.

Which of these forces acts between molecules of the same kind? Between molecules of different kinds? Between masses?

CHAPTER IV.

MEASUREMENT OF TEMPERATURE.

EXERCISE 10. Thermometers.

OBJECT: A comparative study of thermometers.

APPARATUS: Centigrade thermometer.
Metric rule.

DIRECTIONS: Examine a thermometer carefully. How is it made? Note the markings on the scale. What do they indicate? What two points on the thermometer seem of special importance? On this, the centigrade thermometer, zero degree is the freezing point of water and 100 degrees the boiling point. Can you suggest a way of determining these points? After they are located how would you find the length on the scale of one degree?

On your note paper draw a straight line about 20 cm. (centimeter) in length. On the right side of the line place two points, one for the boiling point, the other for the freezing point. Between these points mark the 10, 20, 30, etc to 100 degrees. Continue the line representing the thermometer tube below 0 degrees far enough to admit negative 40 degrees. On the left side mark 212 degrees opposite boiling and 32 degrees opposite freezing. How many degrees on this the Fahrenheit thermometer, are there between freezing and boiling? On the side opposite the 10, 20, 30 (degrees) etc., markings of the Centigrade thermometer, fill in the corresponding numbers of the Fahrenheit thermometer. Find the value of one degree Centigrade in terms of Fahrenheit degrees.

Of one degree Fahrenheit in terms of the Centigrade degree.

Problems: 1. Fifteen degrees C. are equal to how many degrees F?

2. Forty-five degrees F. are equal to how many degrees C.?

3. The Centigrade thermometer registers 21 degrees. What does the Fahrenheit thermometer register at the same time?

4. The Fahrenheit thermometer registers 14 degrees. What does the Centigrade thermometer register at the same time?

CHAPTER V.

EFFECT OF HEAT ON THE STATE OF MATTER.

It is a well-known fact that if any substance is held in a flame, its temperature is increased. The cause of this increase is called heat. To measure this increase some unit of measure is necessary. To this unit the name gram-calorie has been given. A gram-calorie is the amount of heat necessary to raise one gram of water one degree C.

EXERCISE 11. Measurement of the Heat of a Flame.

OBJECT: To determine the amount of heat given off by a given flame in one minute.

APPARATUS: Flask.
Thermometer.
Asbestos cover for flask.
Flame protector.
Wire gauze.
Bunsen burner.
Ring stand.

DIRECTIONS: Place 100 cc. of water in the flask and set it aside. From the ring stand suspend the flame protector. Adjust it in such a manner that the lower

part of the protector fits over the upper part of the Bunsen burner. Then place the wire gauze upon the ring. Light the Bunsen burner and regulate the gas and air for a blue flame of moderate size. Place the burner under the protector. Do not change these adjustments until the experiment is completed.

Take the temperature of the water in the flask. Cover the flask with asbestos cover, and place it on the wire gauze, noting the exact time this is done. Note and record the rise in temperature of the water each minute for ten minutes. Then turn off the gas.

Tabulate results as follows:

Am't of water	Temp.	Time	Inc. per min.	Av. Inc.
Beginning		1		
		2		
		3		
		4		
		5		
		6		
		7		
		8		
		9		
End.		10		

What is the average number of degrees of rise of temperature per minute? How many cc. of water were increased this amount per minute? Then how many calories of heat was your flame giving off per minute?

EXERCISE 12. Change from Solid to Liquid.

OBJECT: To determine the heat necessary to convert one gram of ice to water.

APPARATUS: Cracked ice. Chemical thermometer.
Balance and weights. Asbestos cover.
Hot water. Tin beaker.

DIRECTIONS: Surround the tin beaker with the asbestos cover and ascertain the weight of both. Into the beaker pour 200 cc. of water at 60 degrees C. Now obtain the weight of the beaker and water. Break 75 grams of ice into small pieces. After noting the exact temperature of the water in the beaker, wipe dry the pieces of ice and drop them into the water piece by piece. When the ice is about melted note again the exact temperature of the water. Weigh again the beaker and its contents. Tabulate the data as follows:

1. Weight of beaker and cover.
2. Weight of hot water and beaker.
3. Weight of hot water (calculated).
4. Weight of beaker and water at end of experiment.
5. Weight of ice (calculated).
6. Temperature of water before ice was added.
7. Temperature of water after ice was melted.
8. Loss in temperature of water (calculated).
9. Increase in temperature of ice (calculated).

Multiply the weight of the hot water by its loss in temperature to obtain the number of calories required to melt the ice and raise it to the final temperature. Multiply the weight of the ice by its increase in temperature to obtain the number of calories used in raising its temperature. The difference between these results will give the number of calories used in melting the given amount of ice. How many calories are required to melt one gram of ice?

EXERCISE 13. Change of Liquid to Gas.

OBJECT: To determine the heat necessary to convert 1 cc. of water into steam.

APPARATUS:
See Exercise 11.

DIRECTIONS: Set up apparatus as in Exercise 11. Obtain the force of the flame as in that exercise. Continue to heat the water, noting the exact instant when it begins to boil. Allow it to boil for ten minutes. Turn off the gas and set the water aside to cool. After cooling, measure the water remaining in the flask.

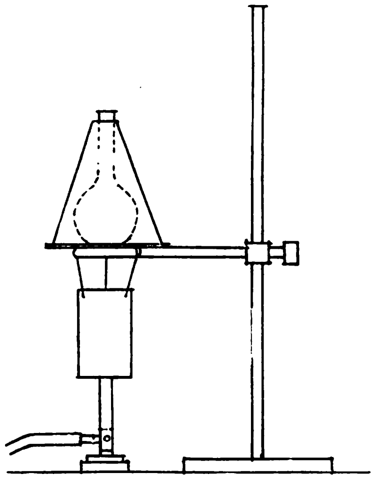


Figure 10

Tabulate data as follows:

1. Amount of water at beginning.
2. Amount of water at end.
3. Loss in water (calculated).
4. Calories given off by flame per minute (calculated).
5. Length of time water boiled.
6. No. of calories used in boiling away water (calculated).
7. No. of calories required to boil away 1 cc. of water (calculated).
8. Did the thermometer rise during boiling?
9. What became of the heat?

CHAPTER VI.

CHANGES IN MATTER.

EXERCISE 14. Physical Change.

OBJECT: To determine the nature of a physical change.

APPARATUS: Salt.

Distilled water.	Bunsen burner.	Ring stand.
Evaporating dish.	Glass stirring rod.	Wire gauze.

DIRECTIONS: Place some salt in an evaporating dish. Cover it with distilled water. Stir it with the glass rod. What happens to the salt? Place the evaporating dish with the solution on the wire gauze over the flame. Heat the solution slowly until all the liquid is evaporated, being careful not to burn the substance left in the dish. Taste the residue. What is it? Has its form changed? Its nature? Changes which do not involve a change in the composition of substances are called *physical* changes. Name five physical changes.

EXERCISE 15. Chemical Change.

OBJECT: To determine the nature of a chemical change.

APPARATUS: Sugar.

Sulphuric acid.	Glass stirring rod.	Wire gauze.
Evaporating dish.	Bunsen burner.	Ring stand.

DIRECTIONS: Cover some sugar in the evaporating dish with sulphuric acid. Stir the substance with the glass rod. What happens? Place the solution on the wire gauze and slowly heat it. What happens? Does the resulting substance resemble either the acid or the sugar with which you started?

Changes which involve a change in the composition of substances and result in the formation of new substances, are called *chemical* changes. Name five chemical changes.

CHAPTER VII.

CHEMICAL PHENOMENA.

All matter has been found to be composed of one or more simple substances known as elements. Chemical elements are characterized by the fact that they cannot be resolved into simpler substances by any known means. Among the more common elements may be mentioned: oxygen, hydrogen, carbon, gold, silver, iron, nitrogen, etc. When two or more elements combine chemically, the new substance formed is called a chemical compound. Salt is a compound, being composed of the two elements sodium and chlorine.

EXERCISE 16. Chemical Synthesis.

OBJECT: To determine the formation of compounds.

APPARATUS: Iron filings.
Flowers of sulphur.
Test-tube.
Test-tube holder.
Bunsen burner.

DIRECTIONS: Note carefully the nature of the elements, iron filings and sulphur. Place equal quantities of each in a test-tube. Shake them well together. Heat the mixture gently over the Bunsen flame. After a few minutes examine the substance. Does it resemble either iron or sulphur? The new substance is a compound and is called iron sulphide.

As another illustration of synthesis burn some flowers of sulphur in the air. Note the odor of the gas given off.

This gas is a compound, (sulphur dioxide) formed by the union of the oxygen of the air with the sulphur. The process in which an element or a compound combines with oxygen is given the special name of oxidation.

EXERCISE 17. Chemical Analysis.

OBJECT: The decomposition of compounds.

APPARATUS: Mercuric oxide.
Hard glass test-tube.
Test-tube holder.
Pine splinter.
Bunsen burner.

DIRECTIONS: Note carefully the properties of mercuric oxide. Place a very small amount of it in a test-tube and heat thoroughly. With the test-tube in the flame insert a lighted pine splinter into the tube. What is the effect on the flame? Is the gas in the tube air? Does it possess any properties of air? Why? Examine the sides of the tube. What do you find there?

This process of decomposing mercuric oxide into the elements mercury and oxygen is called chemical analysis.

CHAPTER VIII.

CHEMICAL ELEMENTS.

EXERCISE 18. Carbon.

OBJECT: To determine some of the properties of Carbon.

APPARATUS: Wood charcoal.
Lime water.
Test-tube.
Beaker.
Pine splinter.
Crushed marble.
Dilute hydrochloric acid.

DIRECTIONS: One of the forms in which carbon occurs is charcoal. Examine a stick of wood charcoal. What is the color? Is it soluble in water? Light the stick of charcoal. Does it burn freely? Does it give off any odor in burning? Thrust the lighted charcoal into the mouth of a test-tube containing some clear lime water. Allow the charcoal to burn in the tube for a minute, then remove it and mix the lime water with the gas in the tube by shaking. What is the effect of the gas on the lime water? Then what must this gas be? (See Exercise 4.)

Rinse the test-tube with water. Again place some lime water in it. Light the pine splinter and thrust it into the test-tube. Remove the splinter and shake the lime water. What change do you note in the lime water? Does wood contain carbon?

Place a few pieces of marble in a clean test-tube. Pour on it a little dilute hydrochloric acid. What happens?

This is a chemical action between the marble and the acid. Over the mouth of this test-tube place the mouth of another to collect some of the gas given off. Remove the second test-tube, pour into it some lime water and shake. What is the effect on the lime water? What does this indicate? Hydrochloric acid contains no carbon. Does marble?

What are the properties of carbon as found in charcoal? In what substances did you find carbon? What other forms of carbon do you know?

EXERCISE 19. Phosphorus. (Demonstration.)

OBJECT: To determine the properties of phosphorus.

APPARATUS: Yellow phosphorus.
Red phosphorus.
Evaporating dish.
Forceps.
Knife.
Filter paper.

DIRECTIONS: (CAUTION — Yellow phosphorus should be kept under water and cut under water. It should not be allowed to come in contact with the bare skin.)

With the forceps place a small piece of yellow phosphorus in the evaporating dish, which has been filled with water. Cut off a piece with the knife. Does it cut easily? What is the appearance of the new cut surface? What is the consistency of phosphorus? Pick up a small piece with the forceps and hold it in the air a moment. What takes place? Does phosphorus give off an odor in burning? Why is it kept under water? Rub phosphorus on a piece of filter paper and examine the paper in the dark

room. What do you see? Will phosphorus burn at a low temperature?

Place a small piece of freshly cut phosphorus in a dish of water exposed to the light. Cover with a bell-jar and leave for at least 48 hours. Does any change in color occur? Examine a small quantity of red phosphorus. Compare in all details its properties with those of yellow phosphorus. What is the difference between an ordinary and safety match?

EXERCISE 20. Sulphur.

OBJECT: To determine the properties of sulphur.

APPARATUS: Flowers of sulphur.
Deflagrating spoons.
Roll sulphur.
Test-tube.
Beaker.
Silver spoon.
Bunsen burner.
Test-tube holder.

DIRECTIONS: Examine a little of the flowers of sulphur. What is its nature? Color? Has it any odor? Taste? Place some of it in a test-tube and cover with water. Does it dissolve?

Slowly heat a little sulphur in a test-tube. What change takes place? What is its color? Continue to heat slowly and watch very carefully the change in consistency and color. When the substance thickens and turns a darker color, pour part of it into a beaker of cold water. Immediately work the substance in the water with the fingers. What is its nature? Is it elastic?

Continue to heat the sulphur in the test-tube. What collects on the sides of the tube? What is it? Examine

some roll sulphur. How does it differ from the flowers of sulphur? Place a little sulphur in the deflagrating spoon and ignite it. Does it burn easily? What is the color of the flame? Do the fumes have an odor? When sulphur burns it forms a gas called oxide of sulphur, or sulphur dioxide.

Place some sulphur in the bowl of a silver spoon or on a silver coin. Heat it slightly. What is the effect of sulphur on silver? The compound formed is called sulphide of silver.

Enumerate the properties of sulphur you have learned.

EXERCISE 21. Iron.

OBJECT: To determine some of the properties of iron.

APPARATUS: Iron wool.
Iron filings.
Magnet.
Beaker.

DIRECTIONS: Place some of the iron filings on a piece of paper. Slowly bring the magnet in contact with the filings. Raise the magnet. Are there filings attached to it? Are other things attracted to it in the same way? To answer this question try the magnet on a silver coin, a penny, a pin, a piece of gold, etc.

Moisten some iron wool and set it aside in a beaker for forty-eight hours. What is the appearance of the iron wool at the end of that time?

Do you know what this reddish deposit is? This is a compound which iron forms with the oxygen of the air in the presence of moisture. From your general observations what other properties of iron could you add to this list?

EXERCISE 22. Oxygen.

OBJECT: To determine the properties of oxygen.

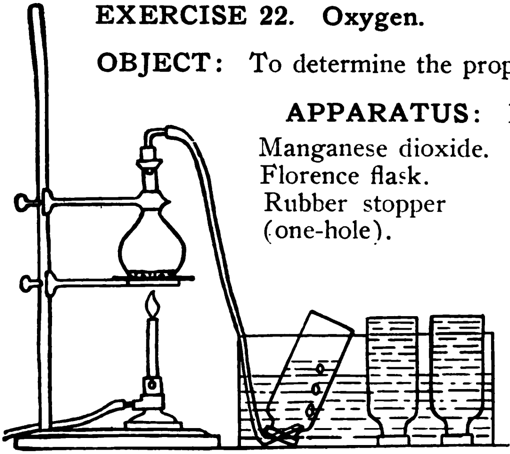


Figure 11

APPARATUS: Potassium chlorate.
Manganese dioxide.
Florence flask.
Rubber stopper (one-hole).
Pneumatic trough.
Delivery tubes.
Ring stand.
Wire gauze.
Bunsen burner.
Large mouth bottles.
Glass plates.
Deflagrating spoon.
Charcoal.
Sulphur.
Pine splinter.

DIRECTIONS: Place in the flask a mixture of four parts of potassium chlorate and one part of manganese dioxide. Insert into the mouth of the flask the rubber stopper carrying the delivery tube. Place the free end of the tube in the pneumatic trough. Place the flask on the wire gauze over the flame of a Bunsen burner and heat gently. By heating the mixture a gas, called oxygen, is given off. Allow the first gas from the flask to escape. Why? Then place the delivery tube under the mouth of an inverted bottle filled with water. When the bottle is filled with oxygen, cover it with a glass plate and set it aside. Fill five other bottles with oxygen in the same manner.

1. Examine the gas in one bottle. Has it any color? Any odor?

2. Place a piece of charcoal in the deflagrating spoon and heat it until it glows. Quickly thrust it into a bottle of oxygen. Note the result. What are the fumes given

off from the burning charcoal? To determine this pour some lime water into the bottle and shake. What property does this show oxygen to possess?

3. Into the deflagrating spoon place some powdered sulphur. Light the sulphur and lower it into a bottle of oxygen. What is the result? After the sulphur has burned smell the fumes in the bottle. What are they?

4. Burn a pine splinter until a good ember is formed. Extinguish the flame and thrust the glowing ember into a bottle of oxygen. What happens? Does oxygen burn? Does it support combustion? Is it found in the air? Why do you think it is or is not found in the air?

Summarize the properties of oxygen you have learned from this exercise.

EXERCISE 23. Hydrogen.

OBJECT: To determine the properties of hydrogen.

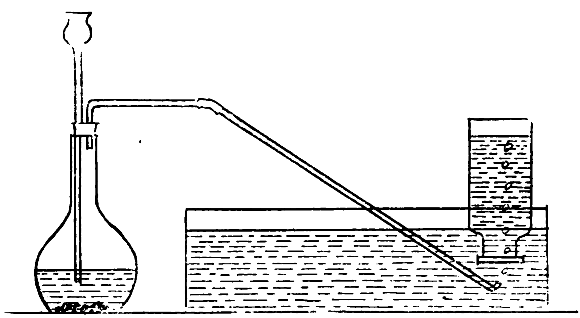


Figure 12

APPARATUS: Granulated zinc.

Dilute hydrochloric acid.	Delivery tube.
Flask.	Pneumatic trough.
Test-tubes.	Pine splinter.
Thistle tube.	Large mouth bottles.

DIRECTIONS: Place a handful of zinc in the flask. Into the mouth of the flask insert a rubber stopper, fitted with the thistle tube and the delivery tube. Pour enough hydrochloric acid through the thistle-tube into the flask to cover the zinc. What action is observed? This is a chemical action between the zinc and the acid. The gas given off is hydrogen. Allow the gas to escape from the delivery tube for a few seconds. Why? Fill a number of bottles with hydrogen by the downward displacement of water. Keep the bottles inverted.

1. Examine the hydrogen in one of the bottles. Has it any color? odor? taste?

2. With the mouth downward, thrust into a second bottle of hydrogen, a lighted splinter. What is the result? Does the splinter continue to burn? Does the hydrogen burn? If so, what is the color of the flame? Examine the sides of the bottle? What do you find there? Where did it come from? What is oxide of hydrogen?

3. Allow a third bottle of hydrogen to stand mouth upward for three minutes. Then insert a lighted splinter. Is the hydrogen still there? Is hydrogen lighter or heavier than air?

EXERCISE 24. Nitrogen.

OBJECT: To determine the properties of nitrogen.

APPARATUS: Ammonium nitrite.

Flask.	Bunsen burner.
Rubber stopper.	Wire gauze.
Delivery tube.	Wide mouth bottles.
Pneumatic trough.	Glass plates.
Ring stand.	Pine splinter.

DIRECTIONS: Place a small quantity of ammonium nitrite in a flask. Heat applied to ammonium nitrite liberates nitrogen. Fit the flask with the rubber stopper

carrying the delivery tube. Place the flask on the wire gauze over the Bunsen flame. Heat gently and allow the first gas to escape. Fill a number of bottles with water and invert them on the stage in the pneumatic trough. Fill the bottles with nitrogen from the flask by downward displacement of water.

1. Examine a bottle of nitrogen. Has it color? odor? taste?

2. Into a second bottle of nitrogen insert a lighted splinter. Does the splinter continue to burn? Does the nitrogen burn?

What are the properties of nitrogen learned?

CHAPTER IX.

AIR AND WATER.

EXERCISE 25. Composition of Air.

OBJECT: To determine the composition of air.

APPARATUS:

Pneumatic trough.
Bell jar.
Evaporating dish.
Phosphorus.
Lime water.
Beaker.
Glass plate.
Pine splinter.

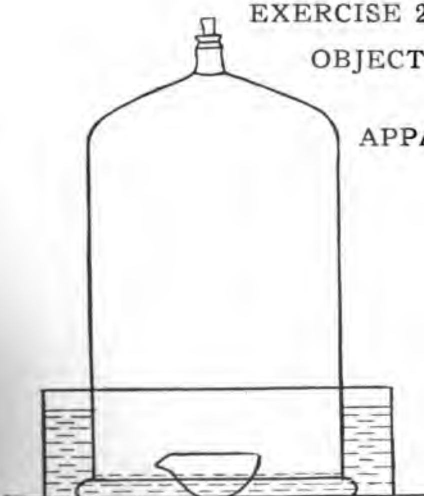


Figure 13

DIRECTIONS: Fill the beaker with lime water and leave it exposed to the air for 48 hours. At the end of that time examine the appearance of the surface of the water. What does this indicate? What then forms a part of the air?

Does wood burn in the air? What element does this indicate to be present? How does the burning of a pine splinter in the air compare with the burning in exercise 22, part 4? What does this indicate?

Pour water, of room temperature, into the pneumatic trough. On the surface of the water, float the evaporating dish containing a piece of phosphorus the size of a small pea. Ignite the phosphorus and cover quickly with the bell jar. What is the result? With what does the phosphorus unite in burning? When does it stop burning in the jar? What are the white fumes? Leave the experiment until these fumes have been dissolved in the water. Does the water rise in the jar? What part by volume does it occupy? This represents the approximate proportion of oxygen in the air.

Slip a glass plate over the mouth of the bell jar and invert it. Examine the gas. Has it color? odor? Will it support combustion? Does it burn? What is this gas? (See Exercise 24.)

Air is a mixture of gases of which the above are the chief ones.

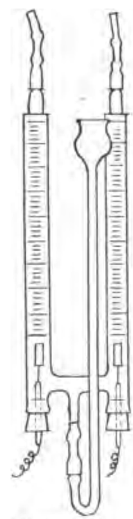


Figure 14

EXERCISE 26. Composition of Water.

OBJECT: To determine the composition of water.

APPARATUS: Electrolysis apparatus. Sulphuric acid (5%). Pneumatic trough. Electric current. Pine splinters.

DIRECTIONS: Fill the apparatus with water containing 5% sulphuric acid. When the apparatus is almost filled, into each arm insert the burette, at the same time opening the cock to drive out the air. After the burettes are completely filled, connect the positive and negative poles of the series with the city current. Note what happens. From what place do the bubbles arise? In which tube do they form more rapidly?

What is the ratio by volume of the gases in the two tubes? This may be accurately obtained by taking the readings on the burettes. When the tube containing the most gas is three-fourths full, disconnect the current. Remove the entire apparatus into a trough of water, so that the open ends of the arms are submerged. Then remove each burette separately, the one of less volume first. Cover the mouth of the burette with the finger and invert. Remove the finger and quickly insert a lighted splinter into this gas. What happens? What is this gas?

Remove the other burette in the same manner as the first. Hold the mouth downward and insert a lighted splinter. What happens? What is this gas? See Exercise 23.

Of what elements is water composed? What proportion by volume?

CHAPTER X.

ACIDS, BASES AND NEUTRAL SUBSTANCES.

EXERCISE 27. Acids and Bases.

OBJECT: To determine the properties of acids and bases.

APPARATUS: Hydrochloric acid (dilute).
Nitric acid (dilute)
Sodium hydroxide.
Ammonium hydroxide.
Red litmus paper.
Blue litmus paper.
Glass rod.

DIRECTIONS: Examine some of the dilute hydrochloric acid. Describe its odor. Dip the glass rod into the acid and touch it to the tip of the tongue. What is its taste? Rub some acid between the fingers. Describe its "feel." Dip a piece of red litmus paper into the acid. What is the effect of the acid on the paper? Dip a piece of the blue litmus into the acid. What effect does the acid have on the blue paper?

Apply the above tests to the nitric acid. Are the results the same as those obtained with the hydrochloric acid? These are methods commonly used to detect any acid.

Examine some sodium hydroxide. Describe its odor, taste, "feel," using the methods given in the study of acids. Test this substance with both red and blue litmus paper. What are the results? Examine ammonium hydroxide in the same manner. How do the results com-

pare with those obtained with sodium hydroxide? These substances are called bases. All bases react similarly to these tests.

EXERCISE 28. Salts and Neutralization.

OBJECT: A study of neutralization and its results

APPARATUS: Hydrochloric acid (10%).
Sodium hydroxide (10%).
Evaporating dish.
Red litmus paper.
Blue litmus paper.
Glass rod.
Bunsen burner.

DIRECTIONS: Pour one cubic centimeter of hydrochloric acid into the evaporating dish. To this add, drop by drop, some sodium hydroxide. Stir constantly to mix the liquids. Test the solution frequently with both kinds of litmus paper. If too much sodium hydroxide is added, the solution will turn the red litmus paper blue; if too much acid is present the blue litmus will turn red. Balance the solution by alternately adding a few drops of acid and base until neither litmus paper is affected. When a solution has no effect on either red or blue litmus paper, it is said to be neutral. The process of mixing an acid and base to produce a neutral substance is called neutralization.

Over a flame evaporate the solution. Examine the residue. What is its appearance? Does it taste like any substance with which you are familiar? What effect does it have on litmus paper? This product is called a neutral salt. Dissolve some of it in water. Does the solution have any effect on litmus paper? What was the substance evaporated? What then, are the products of neutralization?

CHAPTER XI.

CLASSIFICATION OF FOODS.

Substances which are taken into the body as nourishment are known as foods.

Foods contain many elements, chief of which are carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus and iron.

These elements do not occur in living matter as elements, but in various combinations or compounds. These compounds in foods are known as foodstuffs. There are five such foodstuffs.

Proteids, or nitrogenous compounds.
Carbohydrates, or starches and sugars.
Hydrocarbons, or fats and oils.
Mineral salts.
Water.

Each foodstuff shows certain definite qualities by which its presence may be detected.

EXERCISE 29. Tests for Foodstuffs.

OBJECT: To determine a test for proteid, starch, sugar, fat and oil.

APPARATUS: Cornstarch.

Grape sugar.	Ammonia.
Egg-white.	Benzine and ether.
Mutton tallow.	Unglazed paper.
Ground flax seed.	Test-tubes.
Iodine.	Evaporating dish.
Fehling's solution.	Filter paper.
Nitric acid.	Bunsen burner.
Hydrochloric acid.	Stirring rod.

DIRECTIONS:

A. Test for Starch: Place a small amount of corn-starch in a test-tube. Add water and shake the mixture. Does the starch dissolve? To answer this question compare this mixture with a solution of salt and water. Boil the mixture. What change do you note? Dip the end of a glass stirring rod into the paste. Over the paste on the glass rod pour a few drops of iodine. What is the result?

B. Test for grape-sugar: Place a small amount of grape sugar in a test-tube and add enough water to dissolve it. What is the difference in the effect of water on sugar and starch? Add a few drops of Fehling's solution and boil. What change do you observe? To a solution of cane sugar add Fehling's solution and boil. Do you obtain the same result? Take a fresh solution of cane sugar, add a few drops of hydrochloric acid, and then Fehling's solution and boil. How does this result compare with the two preceding? Thus cane-sugar is converted into grape-sugar by the acid.

C. Tests for proteid: Into a test-tube half full of water, place some raw egg-white. Heat this over the Bunsen flame. What is the effect of heat on the egg-white? Pour off the water. Cover the egg-white with dilute nitric acid and boil. What is the color of the egg? Pour off the acid. Add enough ammonia to cover the egg. What is the color produced?

D. Tests for oil and fat: To four teaspoonfuls of ground flax seed, add an equal volume of benzine or ether. Thoroughly stir the mixture and let it stand for about ten minutes. Filter and place the filtrate aside in a strong draught of air until the benzine or ether has entirely evaporated. What is the substance left? What is the odor? Why are benzine and ether used to remove grease spots from clothing?

Rub some mutton tallow on the surface of a piece of unglazed paper. Hold the paper over a Bunsen flame to melt the fat. Then hold it to the light. What is the effect of fat or oil on paper? Summarize the tests you have learned for proteid, starch, sugar, fat.

EXERCISE 30: Foodstuffs in Common Foods.

OBJECT: To determine the food-stuffs found in some foods.

APPARATUS: Egg-white.

Milk.	Iodine.
Potato.	Nitric acid.
Apple.	Fehling's solution.
Beans (soaked).	Ammonia.
English Walnuts.	Unglazed paper.
Flour.	Bunsen burner.

DIRECTIONS: Apply the four tests, which you have learned in Exercise 29, to each of the following foods and tabulate your results as follows:

Foods	Starch	Grape Sugar	Proteid	Oil and Fat
Egg-white				
Milk				
Potato				
Apple				
Beans				
Eng. Walnuts				
Flour				

CHAPTER XII.

DIGESTIVE SYSTEM.

EXERCISE 31. Study of the Mouth (Home study).

OBJECT: To study the parts and structure of the mouth.

APPARATUS: Hand mirror.

DIRECTIONS: Take a position with your back toward a strong light and study your mouth cavity with the aid of a hand mirror.

A. Walls of the mouth cavity.

1. How do the walls enclosing the mouth cavity differ from each other? Note the hard portion or roof of the mouth. How far back does it extend? This is called the *hard palate*. The softer portion at the back of the mouth is called the *soft palate;* and hanging down from its free border is a conical projection, the *uvula*. What is its function?

2. What difference do you observe between the outer and inner covering of the cheeks? What are the characteristics of the inner covering or mucous membrane?

B. Salivary glands.

1. Pull aside with the finger one corner of the mouth. Find the small elevation on the inside of the cheek. The duct from one of the salivary glands (parotid gland lying close in front of the ear) opens on this elevation.

2. Lift the tongue and note the glands (sub-lingual) lying just beneath. The ducts from these glands open in the front of the mouth beneath the tongue. Feel them with the tip of the tongue.

3. Find the third pair of salivary glands (sub-maxillary) lying beneath the floor of the mouth just behind the sub-lingual near the angle of the jaw.

C. The tongue.

1. What kind of covering has the tongue? Describe the difference between the upper and under surfaces. Can you see any difference in the size, shape, number, and arrangement of the minute elevations (papillae) on the upper surface?

D. The Teeth.

1. Teeth differ in minor points from one another, but in all, three parts are found: One, seen in the mouth and called the crown of the tooth; a second, imbedded in the jawbone and called the root; and between the two surrounded by the edge of the gum, the neck of the tooth.

2. Count the teeth in the upper and lower jaw. How many in all? Describe the edges of the front teeth (incisors). How many teeth have this sharp cutting edge? How does the tooth, (canine) next to the incisors, differ from the other teeth? What is its function? How many teeth have two points to the crown? These are known as bicuspids. What is the character of the last two teeth? What is their function?

E. Tonsils.

1. The opening from the back of the mouth leads into the throat. Press the tongue down and note the almond shaped elevations at the side of the throat. These are called tonsils.

EXERCISE 32. Alimentary Canal and Digestive Glands (Demonstration).

OBJECT: A study of digestive organs.

APPARATUS: Models of digestive organs.
Charts.

DIRECTIONS: On the models and charts locate the parts of the alimentary canal.

A. At the back of the mouth, the funnel-shaped cavity—the pharynx or throat. What other openings are there into this cavity? What openings lead from this cavity?

Note the gullet or esophagus, a small tube leading from the pharynx to the stomach.

What is the position of the stomach in the body? Its approximate size and shape?

Following the stomach is a long, very much coiled tube, the small intestine. This tube connects with a larger tube known as the large intestine.

B. Glands: Salivary glands of the mouth:
parotid,
submaxillary,
sublingual.

These were studied in Ex. 31.

In the internal walls of the stomach are small glands known as gastric glands. These discharge their secretion into the stomach. Intestinal glands are located in the walls of the first part of the small intestine. Other glands pour their secretion into the small intestine.

These are: **Pancreas.**
Liver.

The pancreas is a long, lobulated gland lying beneath the stomach. The liver, the largest gland in the body, lies just beneath the diaphragm over the stomach.

From the chart make a drawing of the alimentary canal and glands, labelling parts.

CHAPTER XIII.

DIGESTION AND ABSORPTION.

EXERCISE 33. Action of Digestive Juices.

OBJECT: To determine the foodstuffs acted upon by the various digestive juices.

APPARATUS: Litmus paper.
Corn starch.
Milk.
Egg-white (coagulated).
Olive oil.
Hydrochloric acid.
Fehling's solution.
Iodine.
Ammonia.
Nitric acid.
Sodium hydroxide.
Pepsin.
Rennet.
Pancreatin.
Test-tubes.

DIRECTIONS: **A. Mouth.**

Food is first acted upon by a fluid saliva, which is secreted by glands discharging into the mouth.

1. Test saliva with litmus paper. Is it base or acid?

2. Prepare four test-tubes as follows: In

a. put a little thin starch paste to which add a few cc. of saliva;

b. same as **a**, a little starch paste, and saliva, to which add a few drops of hydrochloric acid;

c. put a few small cubes of egg-white and cover with saliva;

d. put a few cc. of olive oil and saliva.

3. Shake the tubes and set them aside for 48 hours, then test:

a. for starch and sugar;

b. for starch and sugar;

c. notice whether the egg is dissolved;

d. notice whether any change has taken place in the oil.

4. Upon which of the foodstuffs does the saliva act?

5. Does it act in an acid or base solution?

B. Stomach.

In the stomach the food comes in contact with the gastric juice. This contains two active substances, pepsin and rennin.

1. Make a solution of pepsin in water.

Prepare five test-tubes as follows: In

a. put a little starch paste, a few drops of pepsin solution and a little dilute hydrochloric acid;

b. put a few pieces of egg-white, a few drops of pepsin and dilute hydrochloric acid;

c. Put a few pieces of egg-white, a few drops of pepsin and a few drops of very dilute sodium hydroxide;

d. Put a little olive oil to which add pepsin solution and a few cc. of hydrochloric acid;

e. Put some milk and add a few drops of rennet (which contains rennin). Note at the end of the recitation. What change do you observe?

2. Shake the tubes and set them aside for 48 hours. Examine the tubes:

a. Test for starch and sugar.

b. Has the egg-white dissolved?

c. Has the egg-white dissolved?

d. Is there any change in olive oil?

3. Upon which foodstuff does pepsin act?

4. Does it act in an acid or base solution?

5. What effect has rennet on milk?

C. Small Intestine:

In the small intestine the food is acted upon by three digestive juices:

Intestinal, which is secreted by glands in the walls of the small intestine;

Bile, secreted by the liver;

Pancreatic, secreted by the pancreas.

1. Make a solution of pancreatin in water.

2. Prepare four test-tubes as follows: In

a. put some starch paste, a few drops of dilute sodium hydroxide, and a few drops of pancreatic solution;

b. put some starch paste, pancreatin solution and a few cc. of hydrochloric acid;

c. put some egg-white, pancreatin and sodium hydroxide;

d. put some olive oil, pancreatin and sodium hydroxide (dilute).

Shake the tubes and set them aside for 48 hours.

Then examine each tube.

a. Test for starch and sugar.

b. Test for starch and sugar.

c. Has the egg-white dissolved?

d. Note the condition of the olive oil.

4. Upon which foodstuffs does pancreatin act?

5. Does it act in an acid or base solution?

Complete the following table:

Digestive fluid	Acid or base	Region of Alimentary Canal	Foodstuff acted on	Digestive product
Saliva				
Gastric				
(pepsin)				
(rennin)				
Pancreatic				

EXERCISE 34. Absorption.

OBJECT: To determine which foodstuffs will diffuse through an animal membrane.

APPARATUS: Cornstarch.
Olive oil.
Egg-white (raw).
Iodine.
Ammonia.
Nitric acid.
Thistle tube.
Animal membrane.
Glass jar.
Ring stand.
Twine.

DIRECTIONS: For the method of setting up the apparatus for this exercise, see **Exercise 3** on **"Diffusion of Liquids thro' an Animal Membrane."** Set up similar experiments, using in place of the molasses in:

a. starch paste,
b. olive oil,
c. raw egg-white.

After 48 hours note any change in the level of the liquids in the thistle tubes. At the same time test the water in which the bulbs of the thistle tubes were suspended:

a. for starch,
b. for oil,
c. for proteid.

Has diffusion taken place in any of the foregoing? In **Exercise 3** did molasses diffuse through the animal membrane? Why is it necessary to have foods digested?

CHAPTER XIV.

RESPIRATORY SYSTEM.

EXERCISE 35. Respiratory Organs and Mechanics of Respiration. (Demonstration.)

OBJECT: To study the organs of respiration.

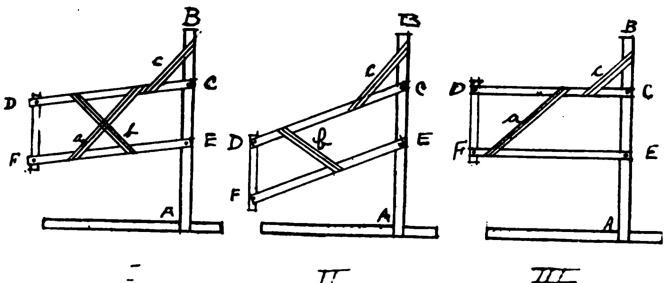


Figure 15.

APPARATUS: Chart or plaster model.
Skeleton.
Mechanical device for rib action.
Bell-Jar with stopper.
Sheet rubber.
Rubber balloon.
Glass tube.

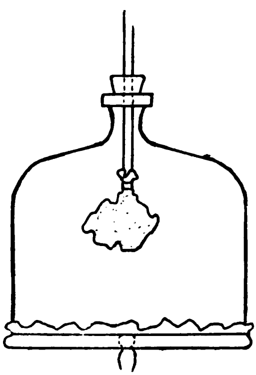


Figure 16

DIRECTIONS: The lungs are the chief organs of respiration. The structure of the lungs will be studied in Exercise 37 in the study of the beef "pluck." Note on the chart or plaster model their position in the body. The cavity in which the lungs and heart are found is the thorax. On the skeleton note the bones forming the frame work of this cavity. The floor of the thorax is a muscular sheet called the diaphragm. Note on the skeleton the attachment of the ribs to the sternum by means of cartilage. This permits the movement of the ribs by the action of the muscles between the ribs called the intercostals.

To demonstrate this movement use the mechanical device.

The vertical bar **AB** represents the **spinal column. DF the sternum. CD and EF two ribs.** Letter **C** rep resents the muscular attachment from the **spine** and **collar bone** to the **ribs.** Letters **a** and **b** represent **intercostal muscles.**

Note on the skeleton that the ribs slant downward toward the sternum. On the device place the bar **DF** lower than points **C.E.** Measure the perpendicular distance between **CE** and **DF.** Then lift the ribs **CD** and **EF** to a position perpendicular to **AB** (in the body this movement is brought about by the contraction of the intercostal muscles). Again measure the perpendicular distance between **CE** and **DF.** How does it compare with the first measurement? How has the position of **DF** been affected? How does this movement affect the size of the thoracic cavity?

The thoracic cavity is enlarged vertically by the movements of the diaphragm. This action is demonstrated by the following experiment:

Fasten the toy balloon to one end of a glass tube. Insert the tube into a rubber stopper and fit this into the

bell-jar with the balloon suspended inside. Over the other end of the bell-jar, securely fasten the rubber sheet to the center of which a handle has been attached. The bell-jar represents the chest walls, the tube the trachea with the balloon as a lung. The rubber sheet represents the diaphragm.

Pull the rubber sheet downward. What happens to the balloon? Then let the rubber sheet return to its normal position. What is the effect on the balloon? The action of the balloon represents the action of the lungs in response to the movements of the diaphragm.

EXERCISE 36. Comparison of Expired and Inspired Air.

OBJECT: To determine the changes which take place in the air while in the lungs.

APPARATUS: Thermometer.
Glass plate.
Wide mouth bottles.
Two-holed rubber stopper.
Glass tubing.
Lime water.
Pine splinter.

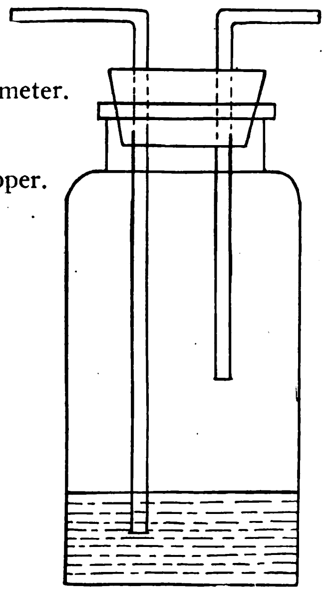


Figure 17

DIRECTIONS: A. Temperature. Expose the thermometer to the room temperature for five minutes and record the temperature. Then breathe on the bulb of the thermometer for a few minutes and record the temperature of expired air. What change has taken place in the temperature of the air while in the lungs?

B. Composition. For the composition of inspired air see Exercise 25.

a. Breathe on the glass plate. What collects on the surface? Does expired air contain more or less moisture than inspired air?

b. Into a wide mouth bottle place lime-water to the depth of an inch. Fit the mouth of the bottle with a rubber stopper fitted with a long and short glass tube. Adjust the long tube so that the end is below the level of the lime water. Draw air from the room through the lime water by suction applied to the free end of the short tube. Continue this for two minutes. Insert the stopper with the tubes into a second bottle containing lime water. Pass expired air through the lime water by blowing into the free end of the long tube. Continue this for two minutes. How does the lime water in the two bottles compare? Which contains the greater amount of carbon-dioxide, inspired or expired air?

C. Fill a bottle with expired air by downward displacement of water. Turn the bottle mouth upward and introduce into it a burning splinter. Does the splinter continue to burn as brightly as in the air? What does this indicate?

Air expired in ordinary breathing has lost about one-fourth of the oxygen contained in inspired air.

CHAPTER XV.

CIRCULATORY SYSTEM.

EXERCISE 37. Study of Beef "Pluck." (Demonstration.)

OBJECT: A study of the relation of the heart and lungs and their structure.

APPARATUS: Beef "pluck," to consist of the trachea, lungs, heart, and its covering, and the main blood-vessels leading to and from the heart.

Plaster model.	Scissors.
Scalpel.	Large glass tube.

DIRECTIONS: A. In what part of the body are these organs located? What is their position to each other? Notice the trachea with its circular rings of cartilage. Are the rings entire? These are necessary to prevent collapse of the tube. How far down do these rings persist? With a scalpel follow a branch of the trachea into the lungs. How do these branches end? (This large amount of branching allows the air to be brought in contact with very small blood vessels, thro' the walls of which oxygen is absorbed in the blood.

B. Lungs. How many lobes has each lung? What are their relative sizes? Note the texture of the lungs. By inserting a glass tube into a branch of one of the bronchi force the air into the lung. What happens? The lungs are the organs chiefly concerned in breathing.

C. Heart. What is the general shape? The covering about the heart is the pericardium. The heart has four compartments. The upper two the auricles (right and

left), the lower two, ventricles (right and left). Which parts have the thickest walls? The walls are made of muscle with the thick-walled parts doing the pumping.

Find the blood vessels, superior and inferior vena cava, leading into the right auricle. Open the veins, also the walls of the auricle, and observe the path of the blood into the right ventricle. Note the tricuspid valve that closes this entrance between auricle and ventricle. Also notice the chords by which this valve is attached to the walls of the heart. What is the effect of the contraction of the ventricle on the action of this valve? Note the pulmonary artery leading from the right ventricle. (To what?) What arrangement is there here to prevent a backward flow of the blood?

In a similar manner open the left compartments of the heart. Do they open into the right side of the heart? Note the entrance of the pulmonary veins (how many?) into the left auricle. Open the left auricle and observe the path of the blood into the left ventricle. How is this entrance guarded to prevent backward passage of blood? This valve is called the *mitral* valve. The thick walled vessel leading from the left ventricle is the *aorta*. The valves at its entrance are the *semilunar valves*. Compare the walls of a vein and an artery as to rigidity and thickness of walls.

EXERCISE 38. Blood.

OBJECT: To determine the nature and composition of blood.

APPARATUS: Three bottles of blood.
Compound microscope.

Glass slides.	Salt solution 1%.
Cover glasses.	Needle.
Alcohol.	Bunsen burner.

DIRECTIONS:

A. Get the butcher to fill a bottle with fresh blood. Set it aside in a cold place, being careful not to jar in the least, the contents. After two days examine the bottle. What is the nature of the contents at this time? The transparent liquid is *serum*. The solid jelly like mass is *clotted blood*. What proportion seems to be serum? What is the color? What is the consistency of the clot? What is its color?

B. Have some blood collected in a pail and whip it rapidly for some time with a brush broom. Fill bottle 2 with the red liquid remaining in the pail and label *defibrinated blood*. Wash the stringy substance clinging to the broom until it is white, then place it in a third bottle in 80% alcohol; label this *blood fibrin*. What was removed from the blood in the whipping? Where is this substance found in clotted blood? Remove a piece of blood fibrin from bottle No. 3. What is its color? Is it elastic? What is the color of defibrinated blood? Place a small quantity in a bottle and shake it for a minute or two. What change has taken place in the appearance of the blood? With what did the blood mix in the shaking? In the human body this change takes place in the lungs.

C. Microscopic study of corpuscles.

Thoroughly clean the end of one of your fingers. Then with a needle that has been sterilized by heating to redness in a Bunsen flame, prick the finger for a small drop of blood. Mount the drop of blood on a glass slide in a small drop of dilute salt solution, and cover with a cover glass. Under the microscope, can you discern solid bodies (corpuscles) in the blood? How many distinct types? How do they compare in number? In size? The smaller are called red corpuscles. How are they arranged? Can you make out their shape? Make two drawings of a red corpuscle, one as seen on end, the other from the side.

The larger bodies are the white corpuscles. Describe them.

CHAPTER XVI.

SKELETAL SYSTEM.

EXERCISE 39. Stucture and Composition of Bone.

OBJECT: To study the structure and chemical composition of bone.

APPARATUS: Section of a long bone (femur).
Beef rib.
Hydrochloric acid 20%.
Glass cylinder.

DIRECTIONS: Examine a long bone. Note the long central shaft with enlarged ends. Of what advantage are the enlarged ends? Note the pinkish colored covering surrounding the bone. What is its function? This covering is the periosteum. Make a longitudinal section thro' the bone. Beneath the periosteum note the hard bone; inside of this the spongy bone and central canal. The spongy bone contains in its cavities red marrow, while the central canal contains yellow marrow.

To determine the chemical composition of bone, place a rib in a twenty per cent solution of hydrochloric acid. Leave the bone in the solution for at least four days. At the end of that time examine the bone. Has it changed in shape? Can it be cut? Is it elastic? The acid has dissolved from the bone the mineral material leaving only the animal matter, cartilage. The animal matter may be extracted by burning the bone. Again the shape remains the same but the substance left is hard and brittle.

This mineral matter is chiefly lime.

EXERCISE 40. Skeleton.

OBJECT: To study the general plan of the skeleton.

APPARATUS: Skeleton.

DIRECTIONS: The skeleton may be divided into three parts, the head, trunk and limbs with the bones to which they are attached, hip and shoulder.

A. Notice that the head is divided into the face and the cranium. The face is composed of a number of irregular bones. The cranium consists of a number of flat bones, sutured together to form a strong covering for the brain.

B. The trunk consists of the spinal column, breast-bone and ribs.

The spinal column is composed of a number of irregular bones called vertebrae. The upper seven are the neck or cervical vertebrae. The next twelve, to which the ribs are attached, are the dorsal vertebrae. The five following are the lumbar vertebrae. The next four in the adult are grown together forming the sacrum. This is followed by five small vertebrae united to form the coccyx.

How do the lower vertebrae compare in size with the upper? What are the advantages of this arrangement?

Note the pads of cartilage between the vertebrae. What is their purpose? Thro' the center of this chain of bones is a canal which contains the spinal cord. How many curves in the back bone? Of what advantage are the curves? Note the flat breast-bone. Of how many bones composed? What bones are attached to it?

How many ribs are there? Where are they attached? How many with one end free? What is their general shape?

C. Limbs.

The shoulder consists of the shoulder blade and collar bone. Locate these. Note the socket formed by their

union for the upper limb. The upper limb consists of the upper arm bone, the humerus; two bones in the forearm, the ulna and radius; eight irregular wrist bones, the carpals; five bones in the palm of the hand, the meta-carpals, and fourteen bones in the fingers, the phalanges.

The hip consists of one large bone on each side. Notice the size and strength of the hip as compared with the shoulder. Why this difference?

The lower limb consists of the upper leg bone, the femur; the two lower leg bones, the tibia and the fibula; the knee cap or patella; seven ankle or tarsal bones; five meta-tarsal and fourteen toe bones or phalanges.

Compare each of these parts with the corresponding parts in the arm.

CHAPTER XVII.

MUSCULAR SYSTEM.

EXERCISE 41. Levers.

OBJECT: To determine the action and advantages of levers.

APPARATUS: Yard stick.
Weight (3 lbs.).
Wire.
Spring balance.
Ring stand.

DIRECTIONS: A lever is an inflexible bar moving about a fixed point, called a fulcrum and having two other points called power and weight. Weight is the mass moved. Power is the force used to move the mass. Weight arm (W.A.) is the distance from the fulcrum to the point of application of the weight.

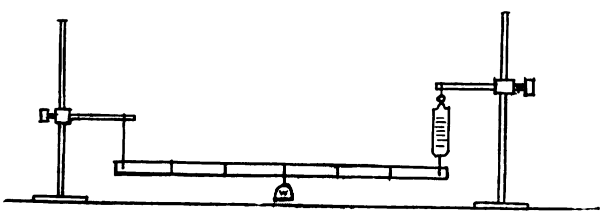


Figure 18

Power arm (P.A.) is the distance from the fulcrum to the point of application of the power.

Levers are divided into three classes based upon the relative positions of the three points fulcrum, power and weight.

In the first class lever, the fulcrum is in the middle, the weight at one end and the power at the other.

The second class lever has the fulcrum at one end, the power at the other end and the weight in the middle.

The third class lever has the fulcrum at one end, the weight at the other end and the power in the middle.

Fasten one end of the yard stick to the ring stand. From the second ring stand suspend the spring balance. Wire the free end of the yard stick to the hook of the spring balance. Take the reading of the indicator on the scale. Suspend the 3-lb. weight from the zero point on the yard stick.

Locate on the apparatus the fulcrum, the power, weight, power-arm and weight arm.

Shift the weight on the bar and record the readings on the balance with the weight at 0, 6, 12, 18, 24, 30 and 36 inches from the fulcrum.

Tabulate your readings as follows:

Power × Power-arm =	Product	Weight × Weight-arm =	Product

How do the two product columns compare? What class lever is used in this exercise?

Of what mechanical advantage is the lever in lifting the 3-lb. weight as shown by the reading at the 6-inch point?

How would you convert this apparatus into a third class lever? Into a first class lever?

EXERCISE 42. Muscles. (Demonstration.)

OBJECT: To determine the structure and action of muscles.

APPARATUS: Frog.
Dissecting pan.
Scalpel.
Scissors.
Needles.

DIRECTIONS: Dissect away the skin of a frog's leg. Note the muscles on the leg. What is the general shape of the muscle? Note the tendon attachment of the muscles to the bone. Of what advantage is the tendon attachment? Note the body of the muscle is surrounded by a thin sheet of connective tissue. Find the large muscle on the calf of the leg. Where are its two ends attached? What effect does the contraction of this muscle have upon the lower leg? Upon the foot? The bones of the skeleton serve as places for muscle attachment and as levers for their action.

CHAPTER XVIII.

EXCRETORY SYSTEM.

EXERCISE 43. Kidney and Skin. (Demonstration.)

OBJECT: To study the structure of the kidney and skin.

APPARATUS: Sheep kidney.
Dissecting pan.
Scalpel.
Scissors.
Skin plaster model.
Thermometer.
Cotton.
Chloroform.

DIRECTIONS: A. Kidney: Slit the capsule surrounding the kidney on the convex side enough to allow the kidney to be removed. Cut the kidney longitudinally from the convex border toward the hilum sufficient to open the cavity within.

Describe the capsule surrounding the kidney.

Where is it attached to the kidney? What is the shape of the kidney? Size? Color? How many tubes do you find connected with this organ? With the longitudinal section of the kidney notice two parts: the outer solid part, the cortex; the inner striated part, the medulla. The slight elevations are called pyramids of Malphigi, between which small tubes may be seen leading into the sinus. The tube leading from the sinus is the ureter which carries the excretion into the bladder. Notice the enlarged end of the ureter in the sinus. Note also the entrance of

the renal artery and the renal vein into the kidney just above the ureter. The artery brings in the blood which gives up its waste in the kidney. This waste is collected by the tubules and emptied from the sinus into the ureter. The capillaries collect the blood which has been cleared of waste and return it to the vein.

B. Skin: The skin also has a part in the work of excretion in the body. It serves two other functions, protection and regulation of bodily temperature.

From a plaster model or a prepared slide of the skin, note the two layers comprising it. The outer layer is the epidermis; the inner is the true skin or dermis. What differences do you note in the two layers? The small bulbous bodies in the dermis are the sweat glands. Note the tubes leading from the glands to the surface. Make a drawing to show these points.

C. Absorption of Heat.

Wrap a small bit of cotton tightly about the bulb of a thermometer. Record the reading of the thermometer. Saturate the cotton with chloroform and wave the thermometer in the air to evaporate the chloroform. As it evaporates what change in temperature do you note? How do you account for this change? See Exercise 13.

Place a drop of chloroform on the back of the hand. What is the sensation produced as the chloroform evaporates? From this exercise what do you conclude concerning the effect of the evaporation of "sweat" on the temperature of the skin?

CHAPTER XIX.

NERVOUS SYSTEM.

EXERCISE 44. Nervous System. (Demonstration.)

OBJECT: To study the brain, spinal cord and nerves.

APPARATUS: Fish.
Dissecting pan.
Scissors.
Scalpel.
Sheep's brain.

DIRECTIONS: Carefully dissect away the roof of the cranium and the dorsal part of the spinal column of the fish to expose the brain and the spinal cord. Note the brain is divided into a number of regions, the small anterior lobes, the olfactory lobes; the larger cerebral hemispheres; the rounded optic lobes; the single lobed cerebellum and behind this, tapering gradually into the spinal cord, the medulla oblongata.

From these centers branches lead to all parts of the head and to some of the internal organs. In the sheep brain note the reduction in the size of the olfactory and optic lobes and the great increase in the size of the cerebrum. Note the convolutions on the cerebrum. In man the increase in the size of the cerebrum is very much greater.

Examine the spinal cord in the fish. Is it of the same dimensions throughout its length? Note the numerous lateral branches. Are they single or in pairs? These are distributed to the remaining parts of the body.

CHAPTER XX.

BACTERIA.

EXERCISE 45. Bacteria.

OBJECT: To show the prevalence of bacteria and something of their nature.

APPARATUS: Petri dishes.
Culture media (agar, gelatin and potato).
Sterilizer.
Inoculating tubes.
Dissecting needle.

DIRECTIONS: Thoroughly sterilize all apparatus and culture media to be used by heating at a temperature of 150°C. for a period of twenty minutes. If an agar or gelatin medium is used, while it is yet in a liquid state, pour into each of eight petri dishes enough of the medium to cover the bottom of the dish. Cover each dish immediately. To insure thorough sterilization, again place these vessels in the sterilizer, and heat at a temperature of 150°C. for fifteen minutes. Set the petri dishes aside to allow the culture medium to harden.

1. After the medium has hardened expose one dish to the air of the laboratory for three minutes. Cover the dish and set it aside until the next recitation.

2. In a similar manner expose the second dish to the air during the sweeping of a floor or while a class is passing. Cover this dish and set it aside.

3. To the surface of the medium of a third dish, touch the edge of a drinking cup. Again cover the dish and set it aside.

4-5. Over the surface of the medium of a fourth dish, spread a drop of milk. Over the surface of the medium of a fifth dish, spread a drop of tap water. Cover each dish and set aside.

6. With a sterilied needle, remove some tartar from the teeth, and spread it on the surface of the medium of the sixth dish. Replace the cover and set aside.

7. Touch the surface of the medium of the seventh dish with the fingers. Replace the cover and set the dish aside.

8. Retain the eighth dish without inoculation as a check on the above seven cultures.

Place all the vessels under similar conditions of heat, light, etc.

Make daily observations for the appearance of colonies of bacteria.

Do growths of bacteria appear in all the dishes? In each instance, where did they come from? How do the growths compare in dishes Nos. 1 and 2? How do you account for the difference? What do these experiments show as to the prevalence of bacteria?

Describe and sketch the appearance of the growths.

From slides (prepared) or charts, the instructor may demonstrate the forms of a few bacteria.

CHAPTER XXI.

VENTILATION.

EXERCISE 46. School Ventilation.

OBJECT: To determine the efficiency of the room ventilation.

APPARATUS: Tape measure.

DIRECTIONS: For a sufficient air supply most authorities agree that an individual requires 300 cu. ft. of space with 1800 cu. ft. of air per hour.

With the tape measure determine the dimensions of the laboratory. From the dimensions what is the volume of the laboratory in cubic feet?

Divide the cubic contents of the laboratory by the number of people in the room. How does the quotient compare with the number of cubic feet of space each individual should have?

What is the method of ventilation in the school building? Learn from those in authority the number of times per hour the air is changed in the room. Compute from this data the number of cubic feet of air each person receives per hour. Is this sufficient for the individual?

Follow the same directions in computing the volume of your session room. Divide the cubic contents by the number of students in the room. Determine the number of cubic feet of air each individual receives per hour. Has each individual the requisite amount of air? If not, what change would you suggest to meet the requirements?

For your own information compute the volume of your sleeping room in cubic feet. How long would the air in the room suffice without change? What means are there for changing the air in the room? Are these sufficient? From what you have learned above correct the fault.

CHAPTER XXII.

SEEDS AND SEEDLINGS.

EXERCISE 47. Structure of Seeds.

OBJECT: To study the structure and parts of seeds.

APPARATUS: Scalpel.
Needles.
Dissecting microscope.
Lima beans (soaked).
Castor beans (soaked).
Corn (soaked).

DIRECTIONS:

1. Lima bean.

(a) External structure. Examine a lima bean. What is its color, size, shape? What are the characteristics of the outer coating, the *testa* of the seed? Note the scar, the *hilum,* on the concave side of the seed. How was this formed? At one end of the hilum, locate a small opening, the *micropyle.* Draw the bean from the side, and from the edge. Label the parts.

(b) Internal structure. With the scalpel carefully open the seed by cutting through the testa along the convex side. Again examine the testa. Within the testa notice the *embryo plant* consisting of:

(a) the cotyledons, two large seed leaves. Are these joined? where?

(b) the plumule, the small rudimentary leaves between the cotyledons:

(c) the hypocotyl, the rudimentary stem and root.

Draw one of the cotyledons showing the plumule and the hypocotyl in position, labelling parts.

2. Corn.

In the bean, the entire contents of the seed consists of the embryo; but this is not always the case. Often as in corn, food is stored in a part called the *endosperm.*

(a) External structure. Examine a kernel of corn. Note the outer covering; also notice the groove where the embryo lies. The hilum and micropyle are at the small end of the kernel. Draw the flat side of the kernel showing the position of the embryo.

(b) Internal structure. Remove the skin. Cut the kernel lengthwise perpendicular to the flat surface. Most of the outside of the kernel consists of a white flowery substance, the endosperm. Of what use is this? Find the embryo. Locate the plumule, radicle, or root and the cotyledon. Compare each of these parts with corresponding parts in the bean. Draw a longitudinal section of the corn, showing and labelling the cotyledon, plumule, radicle and endosperm.

3. Castor bean.

Compare the parts of the castor bean with those of the lima bean and corn.

EXERCISE 48. Conditions for Germination.

OBJECT: To determine the best conditions of temperature, moisture, and air supply for the germination of seeds.

APPARATUS:
- Wide mouth bottles.
- Rubber stoppers.
- Blotting paper.
- Thermometer.
- Scalpel.
- Soaked seeds, peas, corn, etc.
- Refrigerator.
- Oven.

DIRECTIONS: A. Relation of temperature to germination.

In the bottom of each of the four wide mouth bottles, place several layers of thoroughly moistened blotting paper. In each bottle put twelve soaked pea seeds. With the conditions of moisture, light and air supply the same for all bottles, place them in different but fairly constant temperature. Place:

1. the first bottle on the ice in the refrigerator;
2. the second bottle on the shelf in the refrigerator;
3. the third bottle in the room;
4. the fourth in an oven at a temperature of 100 F.

With a thermometer obtain and record the exact temperature in each instance. Make daily observations for a week, tabulating your results as follows:

Bottle	Temp.	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
A_1						
A_2						
A_3						
A_4						

What do you conclude from the above experiment as to the best temperature condition for the germination of peas?

B. Relation of moisture to germination.

Place seeds in four wide mouth bottles as follows:

1. twelve dry seeds in a bottle in which there are several layers of barely moistened blotting paper;

2. twelve soaked seeds in a bottle with barely moistened paper;

3. twelve soaked seeds in a bottle with thoroughly wet paper;

4. twelve soaked seeds in a bottle and almost cover them with water. Place these bottles aside under similar

conditions of temperature, light and air-supply. Make daily observations for a week and tabulate results as above. What do you conclude from this experiment?

C. Relation of air-supply to growth.

Place several layers of blotting paper in each of two bottles. Moisten the paper thoroughly. Fill each bottle one-third full of soaked seeds. Cork one of the bottles tightly making it air tight and leave the other open. With all other conditions the same, set the bottles aside. At the end of 48 hours examine the seeds in each bottle and record results. Is air necessary for germination of seeds?

EXERCISE 49. Seedlings.

OBJECT: A general study of seedlings.

APPARATUS: Wide mouth bottle.
Mosquito netting.
Seedlings, peas, corn, etc.
Scalpel.

DIRECTIONS: A. Make observations on a number of seeds just beginning to sprout. Review the parts of the embryo in Exercise 47. What part of the embryo emerges first from the seed coat? At what point does it come through? Into what part of the mature plant does it develop? Make a sketch to show these points.

B. To determine one of the functions of a cotyledon set up the following experiment:

Fill a wide mouth bottle with water. Cover the mouth of the bottle with mosquito netting. Choose four young seedlings of about the same size each, of corn, pea, and lupine. From two of each kind, carefully remove the cotyledons. Then suspend all the seedlings from the netting with the roots projecting into the water. After a week make observations on the growth of the seedlings with

cotyledons and compare with the growth of those from which the cotyledons were removed.

C. Methods of emerging from the soil.

In a pot of germinating seeds of the castor bean, squash or lima bean, and corn, or any other grain, make observations on various stages of the growth of the seedlings. In the castor bean, squash or lima bean, what part of the seedling emerges from the soil first? In what manner does it come above the surface? Of what advantage is this method to the seedling? Does the arch persist after the cotyledons and plumule are above the surface?

Sketch at least three stages in the above development. Make similar observations on the corn. In what manner does it send its shoot through the soil? Sketch. Examine a number of other seedlings and place them under the proper one of the above classes.

D. The growth above the ground is called the shoot, (stem and leaves) while that below is the root. The points on the stem from which the leaves grow are called nodes. The portion of the stem between two nodes is the internode. Sketch a pea seedling to show nodes and internodes.

Examine well grown seedlings of peas and beans. In each instance where are the cotyledons, above or below the surface of the soil? What is their present condition? What does this indicate as to the function of the cotyledons? What change has the plumule undergone? Is there a new plumule? Sketch to show the above points.

CHAPTER XXIII.

ROOTS.

EXERCISE 50. Kinds of Roots.

OBJECT: To study the kinds and functions of roots.

APPARATUS: Lupine seedlings. Carrot.
Wheat or Oat seedlings. Dahlia roots.

DIRECTIONS: Examine the root of a lupine. Is there a single main branch or several of equal size arising from the same point? These are called the primary roots. The roots growing from the primary are called the secondary roots. Have they any definite arrangement on the single primary root of the lupine? At what angle do they grow from the main root? What function of the root does this suggest? With the lupine compare a carrot, radish, beet or dandelion root. How do the latter differ from the lupine? What other function does this suggest for some roots?

Examine the roots of some grain seedlings. Do they have a single primary root or many fibrous roots? Make observations similar to those made on the lupine root. What difference do you observe? Compare the dahlia root with those of any grain. There are two principal kinds of underground roots. Those growing with a single main branch are called primary tap roots, while those with several main branches are called multiple primary or fibrous roots. An example of the tap root is the lupine; of the fibrous roots the grains. When the tap root is used for food storage, as in the radish, it is called a fleshy tap root. When the fibrous roots store food, as in the dahlia, we have the fleshy fibrous or fascicled roots. Sketch one of each of the above kinds of roots.

EXERCISE 51. Roots as Organs of Absorption.

OBJECT: A study of root hairs.

APPARATUS: Petri dishes.

Blotting paper.	Wide mouth bottles.
Radish seeds.	Perforated corks.

DIRECTIONS: Line the bottom of a petri dish with blotting paper. Moisten it thoroughly and scatter over it a half dozen radish seeds. Cover and set aside for forty-eight hours. At the end of that time examine the roots. The fine hair-like growths found along the surface are called root-hairs. Are they found on all parts of the root? What is the condition of the tip of the root? The little yellow portion over the tip of the root is the root cap which protects the delicate portion of the root tip.

Make an accurate drawing showing the root-hairs and root cap.

To determine the function of root hairs, prepare three vessels as follows:

In the first, cover the bottom with barely moist blotting paper. From a perforated cork, fitted in the vessel, suspend a half dozen radish seedlings. Cover the vessel to retain the moisture.

Line the second vessel with blotting paper. Thoroughly moisten the paper and suspend a half dozen radish seedlings as in the first instance. Cover to retain moisture.

Fill the third vessel with water. Suspend a half dozen radish seedlings from a perforated cork with the roots projecting into the water. Set these experiments aside for 48 hours and observe and record results. What do you conclude from these experiments is the function of root hairs?

CHAPTER XXIV.

STEMS.

EXERCISE 52. Kinds and Structures of Stems.

OBJECT: To study the characteristics of the different kinds of stems.

APPARATUS: Corn stems.
Box Elder twigs.
Scalpel.
Dissecting microscope.

DIRECTIONS: External structure.

Procure a twig of box elder about two feet in length. Examine it carefully, noting the general characteristics of the bark. At intervals on the twig notice the small blister-like elevations, the lenticels. These are openings thro' the bark of young stems for the interchange of gases. On a twig of this season's growth, how are the leaves arranged? On the older portion of the stem note the leaf scars. Do you find any buds on the stem? What relation do they bear to the leaves, or to the leaf scars? Do you find rings of narrow scars on the stem? What difference in the appearance of the stem above and below these rings? From what were these rings of scars caused? How would you determine the age of a branch from the external markings? From the external structure, how would you distinguish a stem from a root?

Internal Structure.

Corn stem: Take an internode of an old corn stalk. Note on the cut end the outer hard rind surrounding the pith. Throughout the pith note the small dots of woody

substance. Break the stalk into two parts. What do you find the small dots to be? Cut a longitudinal section and follow a few of the small fibres. Do they pass the length of the internode? Through the node into the next internode? These thread-like fibres are called fibro-vascular bundles. Make a drawing showing these points. Under the lens of the dissecting microscope examine a cross-section of the corn stem. Are the bundles regularly arranged? Where are they most numerous, near the margin or toward the center? Can you determine of what the rind is composed? Draw to show these points.

Box elder stem: Make a longitudinal section of a small piece of box elder stem. How many parts do you distinguish? Where is the wood in this stem in reference to the pith?

In a cross-section of the stem, locate the parts seen in the longitudinal section. Note the lines running thro' the wood from the pith to the bark. These are lines of pith called medullary rays. How does the arrangement of the wood in the box elder stem differ from that in the corn stem? Make a drawing of both the longitudinal and cross-section of the box elder and label the parts. These stems are examples each of the two classes of stems of flowering plants. The corn stalk is an example of the monocotyledonous type, and the box elder of the dicotyledonous type.

EXERCISE 53. Functions of Stems.

OBJECT: To determine one of the functions of stems.

APPARATUS: Impatiens stem.

Eosin solution.	Beaker.
Potato.	Scalpel.

DIRECTIONS: Cut off a number of branches of the Impatiens, or any other plant with a thin epidermis as Coleus, and immediately place the cut end in a beaker of eosin solution. Similarly cut off the end of a potato and place the cut end in the eosin solution. Set them aside for several hours. Then examine the stems to determine the paths taken by the red solution. To see this more clearly make a longitudinal section of the stem. What part of the stem is stained, the pith, wood or epidermis? Does this stain extend into the leaves? What is its course through the leaves? Break off a leaf from the stem. Examine the end of the leaf stalk. What do the red dots on the end indicate? Through what part of the stem do liquids pass? Make a drawing of a cross section of a stem to show the path of liquids. From general observations can you suggest other functions of stems?

CHAPTER XXV.

LEAVES.

EXERCISE 54. The Parts and Kinds of Leaves.

OBJECT: A study of a few types of leaves.

APPARATUS: Leaves of

Apple,	Maple,
Black Locust,	Lily of the Valley,
Clover,	Canna.

DIRECTIONS: Carefully examine an apple leaf. Note the thin expanded portion, the blade, the leaf stalk or petiole, and the small appendages on both sides of the base of the petiole, the stipules. These are the parts of a typical leaf. However, in some plants one or more of these parts may be lacking. Examine a number of leaves for these parts.

Compare a leaf of the black locust with the apple leaf. How do the blades differ? The separate divisions of the blade of the locust leaf are called leaflets.

A leaf having a blade consisting of one piece is a simple leaf, and a leaf in which the blade consists of several distinct pieces or leaflets is a compound leaf. Draw and label a simple and a compound leaf.

Examine the apple leaf again. Note the continuation of the petiole through the blade. This is called the midrib and its branches the veins. Compare the arrangement in the veins of the lily-of-the-valley leaf with that of the apple leaf. How do they differ? These are examples of the two kinds of venation. Make a drawing of each leaf labelling the apple leaf, netted veined, and the lily-of-the-

valley, parallel veined. Compare the veining of the maple leaf with that of the apple. In what are they alike? How do they differ? The apple leaf is pinnately netted veined and the maple leaf is palmately netted veined. In like manner compare the veining of the lily-of-the-valley with that of the canna leaf. In what respect are they alike? How do they differ? The lily-of-the-valley leaf is palmately parallel veined and the canna leaf is pinnately parallel veined.

LEAVES	**Parts**	**Blade**	
		Petiole	
		Stipule	
	Kinds	**Simple**	
		Compound	
	Venation	**Parallel**	**Pinnately**
			Palmately
		Netted	**Pinnately**
			Palmately

EXERCISE 55. Respiration.

OBJECT: To determine the gas given off in respiration of plants.

APPARATUS: Wide mouth bottles.
Mushrooms.
Green plants.
Lime water.
Pine splinter.
Stoppers.

DIRECTIONS: Fill four bottles to the depth of one-half inch with water. Into two of the bottles place a few shoots of green plants. Into the other two bottles place some mushrooms. Cork the bottles tightly and place them in the dark until the next recitation. What gas was in the bottle when the experiment was set up? What gas is

present in the bottle at the end of the experiment? To determine this insert into one of each of the two sets of bottles a lighted splinter. Note carefully the result. What does this indicate? Test the gas in each of the other two bottles with lime water. What is the effect? What is the gas given off in respiration of plants? How does this compare with the same process in animals? See Exercise 36.

EXERCISE 56. Starch Formation or Photosynthesis.

OBJECT: To determine the conditions for starch formation in plants.

APPARATUS: Nasturtium.
Variegated geranium.
Alcohol. Iodine.
Bunsen burner. Beaker.

DIRECTIONS:

1. The relation of chlorophyll to starch formation. Place a geranium with variegated colored leaves in the bright sunlight for the greater portion of a day. Select a few leaves on the plant and sketch the blades to show the color patterns on them. Remove these leaves and immerse them immediately into boiling water to kill them. The green coloring matter in plants is chlorophyll. After five minutes' boiling place the leaves in a vessel of 96% alcohol to extract the chlorophyll. After the chlorophyll is extracted spread the leaves on a white surface and cover them with a weak solution of iodine. In what part of the leaf is starch found? Has chlorophyll anything to do with starch formation?

2. The relation of sunlight to starch formation. Place a nasturtium plant in the bright sunlight and another in the dark room. On the afternoon of the second

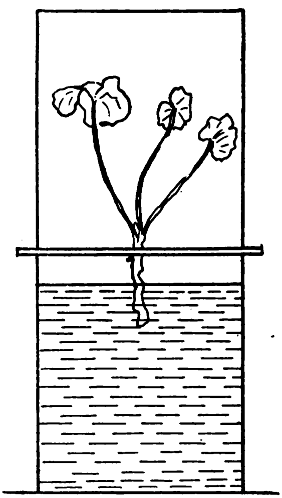
day remove several leaves from each plant being careful to keep the two sets of leaves separate. Kill them and extract the chlorophyll in the same manner as directed in the preceding paragraph. Place the leaves on a white surface and test each for the presence of starch. Is starch found in both sets of leaves? What does this indicate concerning the relation of sunlight to starch making?

EXERCISE 57. Evaporation.

OBJECT: To show that the excess water in plants is given off by the leaves.

APPARATUS:

Glass tumblers.
Card board.
Paraffine.
Geranium.



DIRECTIONS: Cut off a small branch of geranium. Cut a hole in a card board and place the cut end of the geranium through the opening. Fill one tumbler with water and cover it with card board, with the cut end of the geranium extending into the water. Carefully seal the stem into the card board. Paraffine the entire upper surface of the card board to prevent any evaporation of water through it. Over the leaves of the geranium invert a second tumbler and set the experiment aside for a few hours. Then examine the inside of the upper tumbler. How do you account for the condition found?

From the experiments on leaves, what are the functions of leaves? Under what conditions is each carried on?

CHAPTER XXVI.

THE FLOWER.

EXERCISE 58. A Typical Flower.

OBJECT: To learn the parts of a typical flower.

APPARATUS: Trilliums.

Dissecting microscope.	Forceps.
Scalpels.	Needles.

DIRECTIONS: Carefully examine the flower of the trillium. Note the outer whorl of leaf-like parts. How many are there? What is their size and shape? Each of these parts is called a sepal; together they form the calyx. The second whorl of parts form the corolla, each separate part being a petal.

How many petals are there? How are they arranged on the flower stalk in reference to the sepals? How do they compare in size and number to the sepals? What is the nature of the parts of the third cycle of floral parts just inside of the corolla? These are the stamens. How many are there? How are they arranged? Remove a stamen and note the slender stalk, the filament with the enlarged end, the anther. On a mature anther note the powdery substance, the pollen. Make a drawing of a stamen showing these parts.

In the center of the flower is the pistil. The large bulbous base is the ovary and the three parted projection above is the stigma. Examine the stigma carefully. Is its upper surface smooth or rough? Make a drawing of the pistil and label the parts. Make a cross section of the ovary. How many compartments do you find in the

ovary? How many rows of seeds in each compartment? Where are they attached? Draw a cross section of the ovary. Make a diagram of the flower showing its parts and their relation to each other. Examine a number of other flowers to acquaint yourself with the floral parts. The function of the flower is to reproduce its kind. The essential organs of the flower for this work are the stamens and pistils. The stamen bears pollen which is transmitted to the stigma of a like flower, by the wind, insects or other means. The pollen grain germinates on the stigma and sends a tube down into the ovary, where it enters an ovule. A part of the contents of the pollen tube, called the nucleus, unites with the nucleus of the ovule, after which the ovule develops into a seed.

CHAPTER XXVII.

CLASSIFICATION.

EXERCISE 59. Plant Families.

OBJECT: To study the characteristics of one or more plant families.

APPARATUS: Dog-tooth violet.
Bell-Wort.
Wild rose.
Apple
Trillium.
Dissecting microscope.
Scalpel.
Forceps.
Needles.

DIRECTIONS: Examine an entire plant of dog-tooth violet. How are the leaves arranged? What is the type of venation in the leaf? Examine the flower. Are all the parts of the flower present? What is the number of parts in each cycle? What is the nature of the receptacle on which the floral parts are borne? Make a cross section of the ovary. How many compartments are there in the ovary? How many rows of seeds in each? Where are the seeds attached?

Similarly examine the trillium and the bell-wort. What characteristics do these plants have in common? Plants having these same characteristics are grouped together and form what is known as the *lily family*. In like manner examine the flowers of the wild rose and apple. Have they the same number of floral parts in each cycle as members of the lily family? Compare the venation of the apple and rose leaves with the venation of lily leaves. Why would you not place the apple and the rose in the lily family?

What is the number of parts found in each cycle of floral parts in the wild rose? the apple? Is there a single ovary or many? What is the nature of the receptacle? Plants having these charcteristics belong to the rose family.

APPENDIX

APPARATUS.

This list includes all apparatus necessary for a satisfactory presentation of the preceding course. The total cost can be reduced by omitting a few pieces of apparatus, which, while desirable, are not essential.

The physical apparatus and glassware here given should be furnished to each member of the laboratory section, except such pieces as are marked by an asterisk. These are for demonstration and only one piece of each is necessary.

The amount of each chemical required will vary with the size of the class, but the total cost of chemicals will not exceed $10.00.

A. PHYSICAL APPARATUS.

1	Asbestos sheet 8X8 by 16 inches	$ .10
1	Balance spring	.55
*1	Ball and ring	1.10
1	Bladder	.16
1	Bunsen burner	.25
*1	Compound bar	.95
1	Deflagrating spoon	.13
*1	Drying oven	8.50
1	Forceps, dissecting	.40
1	Magnet, bar	.33
1	Metric stick	.35
1	Microscope, dissecting	2.20
2	Needles, Dissecting	.12
1	Pam, Dissecting	.40
*1	Pneumatic trough	1.10
*1	Porous cup	.22
1	Ring stand with two rings, and 1 burette clamp	.90
*1	Rubber balloon	.11